GPS Autonomous Navigation for Groundtrack Repeat Orbits

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ABSTRACT

This paper describes a simple empirical strategy for computing maneuver times and magnitudes autonomously for the Earth orbiting spacecraft with a groundtrack repeat requirement. Using the Global Positioning System (GPS), tracking and orbit determination functions are consolidated in the GPS receiver to produce real-time position estimates. With these estimates, groundtrack drift behavior is examined with a simple empirical model to deduce required maneuver times and magnitudes. Thus, this technique does not require the conventional tools of orbit determination (i.e., numerical integrator for state/state partial propagation and Kalman filter for observation noise filtering). The simplified empirical model also reduces the complexity of the orbit propagation/prediction task required by the maneuver decision and design functions.

Elements of the autonomous navigation system for the TOPEX/Poseidon Follow-On mission include: Global Positioning System (GPS) tracking and orbit determination, maneuver decision, maneuver design, and maneuver implementation. This memorandum proposes a strategy encompassing all elements except the maneuver implementation function.

Tracking System and orbit Determination

For this simplified autonomous navigation strategy, only the spacecraft position is required; thus, the minimum set of observations consists of four simultaneous GPS pseudorange measurements and the GPS space vehicle ephemerides. Point position solutions (navigation solutions) are obtained with a least squares adjustment of the observations to produce estimates of the spacecraft Earth-Fixed cartesian position and GPS receiver clock offset.

GPS provides two levels of service: a Standard Positioning Service (SPS), available to all users on a continuous, worldwide basis with no direct charge and an encoded Precise Positioning Service (PPS) intended primarily for military use. SPS is intentionally degraded with a process called Selective Availability (SA) and has an advertised positioning accuracy of 1 00 meters horizontal and 140 meters vertical (95 percent probability y) [1992

Federal Radionavigation Plan]. For TOPEX/Poseidon, the three-dimensional accuracy of the navigation solutions using SPS is 60 to 70 meters RMS over 1 day.

An important aspect of this simplified method is to use the groundtrack equator crossing offsets for maneuver parameter determinant ion. Equatorial crossing offsets between the GPS navigation solutions and a near truth Precision Orbit Ephemeris (POE) [*Bertiger, et.al.,1994*] compare to approximately 50 meters RMS over 30 days.

The current TOPEX/Poseidon GPS flight receiver software appears to be responsible for an approximately 40 meter bias in the longitude of the ascending node. This bias manifests itself as a 16 meter bias in the alongtrack and 38 meter bias in the ascending equator crossings. Removal of this bias will result in GPS navigation solution equator crossing accuracies of 20 to 30 meters RMS.

Maneuver Decision and Design

For TOPEX/Poseidon, the groundtrack is maintained to ±1 kilometers about a fixed reference groundtrack. Fig. 1 shows the ground track drift history for the first three years of TOPEX/Poseidon. An important feature to note is the quadratic nature of the change in the groundtrack longitude offsets. Between each maneuver, a quadratic (2nd degree polynomial) fit to the longitude offsets produces an empirical model that can be used to predict the next maneuver time and magnitude.

The dominant error source in this approach becomes the misfit of the quadratic to the longitude offsets rather than the orbit determination. Fig.2. shows the quadratic fit to the GPS navigation solutions. The large deviations from the quadratic curve are primary due to luni-solar effects and to a lesser degree the varying atmospheric drag.

Maneuver times are computed by propagating the quadratic and monitoring the west and east boundaries for violations. By examining the maximum west excursion of the ground track from the quadratic model the maneuver magnit ude can be optimized to maximize the time interval between maneuvers.

Preliminary Results

Currently, the TOPEX/Poseidon GPS flight receiver produces navigation solutions once every 10 seconds. Fig 2. shows the longitude offsets derived from the GPS navigation solutions since Orbit Maintenance Maneuver No. 8 (OMM8) on 22 May 1995. Based on GPS observations up to 26 September 1995, the next maneuver is predicted to be required cm 29 October 1995. On that date a AV of 3.32 mm/sec would target the -750 meter west boundary assuming constant drag.

Conclusions

A simplified approach to autonomously computing maneuver parameters for groundtrack repeat missions appears to be feasible. This approach will provide for faster and cheaper development and operations costs with limited degradation compared to the conventional navigation currently used for TOPEX/Poseidon.

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References

Bertiger, W., et al., GPS precise tracking of TOPEX/POSEIDON: Results and Implications, *J. Geophys. Res.*, 99, 24449-24464, 1994.

Federal Radionavigation Plan, 1992.

Figure 1

GROUND TRACK HISTORY

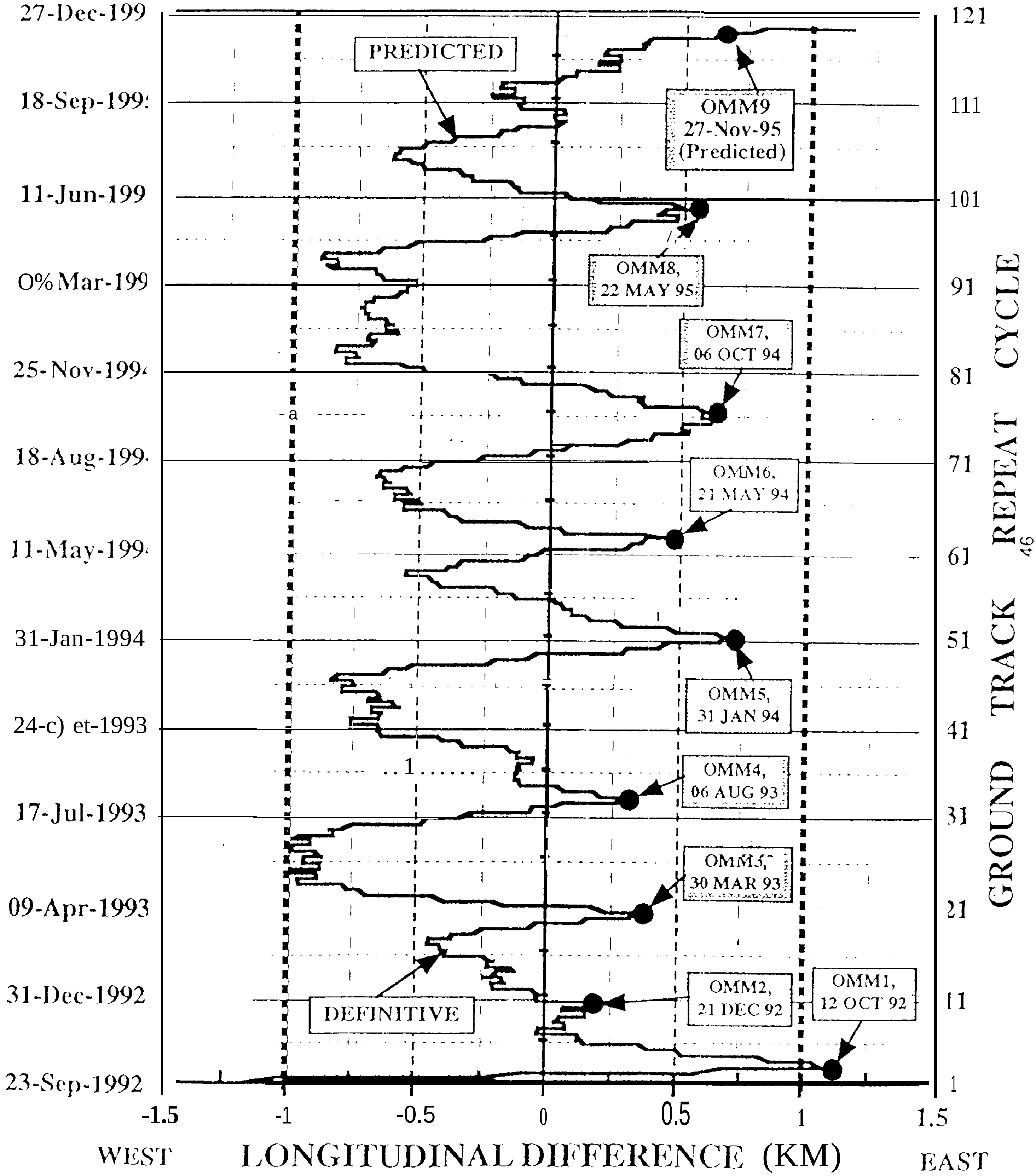

Fig.2 - GPS Navigation Solution Groundtrack Offset